

..CLAIMS

1. A resist-removing solution for low-k film  
comprising hydrogen fluoride (HF) and at least one member  
5 selected from the group consisting of organic acids and  
organic solvents.

2. A resist-removing solution according to  
claim 1, further comprising at least one member selected  
from the group consisting of ammonia and amines.

10 3. A removing solution according to claim 1,  
wherein the solution is used for ultrasonic cleaning.

4. A removing solution according to claim 1,  
wherein the low-k film has a dielectric constant greater  
than 1 but not greater than 3.

15 5. A removing solution according to claim 1,  
whereby a SiN film can be etched to a depth of at least 1  
Å.

6. A removing solution according to claim 1,  
wherein the organic acids or organic solvents have an SP  
20 value of 7 to 17.

7. A removing solution according to claim 1,  
wherein the concentration of HF is in the range of 0.01 to  
10 mass %.

8. A removing solution according to claim 1,  
25 wherein said at least one member selected from the group

consisting of organic acids and organic solvents is organic acid(s) or a mixture of organic acid(s) and organic solvent(s); and the concentration of HF is in the range of 0.01 to 5 mass %.

5           9. A removing solution according to claim 1, wherein said at least one member selected from the group consisting of organic acids and organic solvents is organic solvent(s); and the concentration of HF is in the range of 0.01 to 10 mass %.

10           10. A removing solution according to claim 1, further comprising water, wherein the weight ratio of HF/organic acid/water is in the range of 0.01 to 5 mass %/  
49 to 99.9 mass %/0 to 50 mass %; and the organic acid is at least one member selected from the group consisting of  
15 monocarboxylic acids, sulfonic acids, and polycarboxylic acids.

          11. A removing solution according to claim 10, wherein the monocarboxylic acids are at least one member selected from the group consisting of acetic acid,  
20 propionic acid, butyric acid, isobutyric acid, valeric acid, caproic acid, caprylic acid, monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, monofluoroacetic acid, difluoroacetic acid, trifluoroacetic acid,  $\alpha$ -chlorobutyric acid,  $\beta$ -  
25 chlorobutyric acid,  $\gamma$ -chlorobutyric acid, lactic acid,

glycolic acid, pyruvic acid, glyoxalic acid, methacrylic acid, and acrylic acid;

the sulfonic acids are at least one member selected from the group consisting of methanesulfonic acid, benzenesulfonic acid, trifluoromethanesulfonic acid, and toluenesulfonic acid; and

the polycarboxylic acids are at least one member selected from the group consisting of oxalic acid, succinic acid, adipic acid, tartaric acid, and citric acid.

10           12. A removing solution according to claim 1, further comprising water, wherein the weight ratio of HF/organic solvent/water is in the range of 0.01 to 10 mass %/49 to 99.9 mass %/0 to 50 mass %; and the organic solvent is at least one member selected from the group  
15 consisting of monohydric alcohols, polyols, ketones, amides, nitriles, aldehydes, alkylene glycol monoalkyl ethers, ethers, esters, hydrocarbons, halogen compounds, fluorinated alcohols, phosphate esters, and nitrogen-containing compounds.

20           13. A removing solution according to claim 2, wherein the weight ratio of HF/said at least one member selected from the group consisting of ammonia and amines/organic solvent/water is in the range of 0.01 to 10 mass %/0.01 to 30 mass %/49 to 99.9 mass %/0 to 50 mass %;  
25 and the organic solvent is at least one member selected

from the group consisting of monohydric alcohols, polyols, ketones, amides, nitriles, aldehydes, alkylene glycol monoalkyl ethers, ethers, esters, hydrocarbons, halogen compounds, fluorinated alcohols, phosphate esters, and  
5 nitrogen-containing compounds.

14. A removing solution according to claim 12, wherein the monohydric alcohols are at least one member selected from the group consisting of methanol, ethanol, isopropanol (IPA), 1-propanol, 1-butanol, 2-butanol, t-  
10 butanol, 2-methyl-1-propanol, 1-pentanol, 1-hexanol, 1-heptanol, 4-heptanol, 1-octanol, 1-nonyl alcohol, 1-decanol, 1-dodecanol, lauryl alcohol, and cyclohexanol, with the proviso that methanol and ethanol are used in combination with other organic solvent(s) or organic  
15 acid(s);

the polyols are at least one member selected from the group consisting of ethylene glycol, diethylene glycol, 1,2-propanediol, propylene glycol, 2,3-butanediol, and glycerin;

20 the ketones are at least one member selected from the group consisting of acetone, acetylacetone, methyl ethyl ketone, methyl isobutyl ketone, cyclohexanone, diethyl ketone, and diisobutyl ketone;

the amides are at least one member selected from  
25 the group consisting of N-methylformamide, N,N-

dimethylformamide, N-methylacetamide, and N,N-dimethylacetamide;

the nitriles are at least one member selected from the group consisting of acetonitrile, propionitrile, butyronitrile, isobutyronitrile, and benzonitrile;

the aldehydes are at least one member selected from the group consisting of formaldehyde, acetaldehyde, and propionaldehyde;

the alkylene glycol monoalkyl ethers are at least one member selected from the group consisting of ethylene glycol monomethyl ether and ethylene glycol monoethyl ether;

the ethers are at least one member selected from the group consisting of tetrahydrofuran, dioxane, diisopropyl ether, dibutyl ether, tetrahydropyran, anisole, 1,2-dimethoxyethane, and diethylene glycol dimethyl ether;

the esters are at least one member selected from the group consisting of methyl acetate, ethyl acetate, propyl acetate, isopropyl acetate, butyl acetate, isobutyl acetate, pentyl acetate, hexyl acetate, methyl propionate, ethyl propionate, propyl propionate, isopropyl propionate, butyl propionate, isobutyl propionate, pentyl propionate, hexyl propionate, methyl butyrate, ethyl butyrate, propyl butyrate, isopropyl butyrate, butyl butyrate, isobutyl butyrate, pentyl butyrate, hexyl butyrate, methyl

isobutyrate, ethyl isobutyrate, propyl isobutyrate,  
isopropyl isobutyrate, butyl isobutyrate, isobutyl  
isobutyrate, pentyl isobutyrate, hexyl isobutyrate, methyl  
valerate, ethyl valerate, propyl valerate, isopropyl  
5 valerate, butyl valerate, isobutyl valerate, pentyl  
valerate, hexyl valerate, methyl isovalerate, ethyl  
isovalerate, propyl isovalerate, isopropyl isovalerate,  
butyl isovalerate, isobutyl isovalerate, pentyl  
isovalerate, hexyl isovalerate, methyl caproate, ethyl  
10 caproate, propyl caproate, isopropyl caproate, butyl  
caproate, isobutyl caproate, pentyl caproate, hexyl  
caproate, methyl caprylate, ethyl caprylate, propyl  
caprylate, isopropyl caprylate, butyl caprylate, isobutyl  
caprylate, pentyl caprylate, hexyl caprylate, methyl  
15 octanoate, ethyl octanoate, propyl octanoate, isopropyl  
octanoate, butyl octanoate, isobutyl octanoate, pentyl  
octanoate, hexyl octanoate, methyl nonanoate, ethyl  
nonanoate, propyl nonanoate, isopropyl nonanoate, butyl  
nonanoate, isobutyl nonanoate, pentyl nonanoate, hexyl  
20 nonanoate, methyl decanoate, ethyl decanoate, propyl  
decanoate, isopropyl decanoate, butyl decanoate, isobutyl  
decanoate, pentyl decanoate, hexyl decanoate, methyl  
dodecanoate, ethyl dodecanoate, propyl dodecanoate,  
isopropyl dodecanoate, butyl dodecanoate, isobutyl  
25 dodecanoate, pentyl dodecanoate, hexyl dodecanoate, methyl

- laurate, ethyl laurate, propyl laurate, isopropyl laurate,  
butyl laurate, isobutyl laurate, pentyl laurate, hexyl  
laurate, methyl acrylate, ethyl acrylate, propyl acrylate,  
isopropyl acrylate, butyl acrylate, isobutyl acrylate,  
5 pentyl acrylate, hexyl acrylate, monomethyl oxalate,  
dimethyl oxalate, monoethyl oxalate, diethyl oxalate,  
monopropyl oxalate, dipropyl oxalate, monobutyl oxalate,  
dibutyl oxalate, monomethyl succinate, dimethyl succinate,  
monoethyl succinate, diethyl succinate, monopropyl  
10 succinate, dipropyl succinate, monobutyl succinate,  
dibutyl succinate, monomethyl adipate, dimethyl adipate,  
monoethyl adipate, diethyl adipate, monopropyl adipate,  
dipropyl adipate, monobutyl adipate, dibutyl adipate,  
monomethyl tartrate, dimethyl tartrate, monoethyl tartrate,  
15 diethyl tartrate, monopropyl tartrate, dipropyl tartrate,  
monobutyl tartrate, dibutyl tartrate, monomethyl citrate,  
dimethyl citrate, monoethyl citrate, diethyl citrate,  
monopropyl citrate, dipropyl citrate, monobutyl citrate,  
dibutyl citrate, dimethyl phthalate, diethyl phthalate,  
20 dipropyl phthalate, dibutyl phthalate, dipentyl phthalate,  
dihexyl phthalate, diheptyl phthalate, dioctyl phthalate,  
dinonyl phthalate, didecyl phthalate, didodecyl phthalate,  
dimethyl terephthalate, diethyl terephthalate, dipropyl  
terephthalate, dibutyl terephthalate, dipentyl  
25 terephthalate, dihexyl terephthalate, diheptyl

terephthalate, dioctyl terephthalate, dinonyl  
terephthalate, didecyl terephthalate, didodecyl  
terephthalate, propylene carbonate, and  $\gamma$ -butyrolactone;

the hydrocarbons are at least one member  
5 selected from the group consisting of hexane, cyclohexane,  
octane, isooctane, benzene, and toluene;

the halogen compounds are at least one member  
selected from the group consisting of chloroform, o-  
dichlorobenzene, perfluorohexane, and  
10 perfluoromethylcyclohexane;

the fluorinated alcohols are at least one member  
selected from the group consisting of trifluoroethanol,  
pentafluoropropanol, and 2,2,3,3-tetrafluoropropanol;

the phosphate esters are at least one member  
15 selected from the group consisting of dimethyl phosphate,  
dibutyl phosphate, diphenyl phosphate, dibenzyl phosphate,  
trimethyl phosphate, triethyl phosphate, tripropyl  
phosphate, tributyl phosphate, and triphenyl phosphate;  
and

20 the nitrogen-containing compounds are at least  
one member selected from the group consisting of  
tetramethylurea and N-methyl-2-pyrrolidone.

15. A method of removing resist, comprising  
treating an object having resist on the surface of a low-k  
25 film or on an antireflection coating (BARC) over a low-k



film, by the use of the removing solution of claim 1 under temperature and time conditions such that the resist can be removed without substantially damaging the low-k film.

16. A method according to claim 15, comprising  
5 an ashing treatment for the resist without substantially damaging the low-k film, before treating the object using the removing solution.

17. A method according to claim 15, wherein the low-k film is substantially undamaged because the low-k  
10 film is substantially unetched and/or the dielectric constant of the low-k film is substantially unchanged before and after the treatment.

18. A method according to claim 15, comprising treating the object while performing ultrasonic cleaning.

15 19. A resist-removed object that can be obtained according to the method of claim 15.

20. A cleaning solution for a via hole or a capacitor comprising hydrogen fluoride (HF) and at least one member selected from the group consisting of organic  
20 acids and organic solvents.

21. A cleaning solution according to claim 20, further comprising at least one member selected from the group consisting of ammonia and amines.

22. A removing solution according to claim 20,  
25 wherein the solution is used for ultrasonic cleaning.

23. A cleaning solution according to claim 20, whereby a TiN film can be etched to a depth of at least 0.01 Å.

24. A cleaning solution according to claim 20,  
5 further comprising water, wherein the weight ratio of HF/organic acid/water is in the range of 0.01 to 5 mass %/49 to 99.9 mass %/0 to 50 mass %; and the organic acid is at least one member selected from the group consisting of monocarboxylic acids, sulfonic acids, and polycarboxylic  
10 acids.

25. A cleaning solution according to claim 24, wherein the monocarboxylic acids are at least one member selected from the group consisting of acetic acid, propionic acid, butyric acid, isobutyric acid, valeric  
15 acid, caproic acid, caprylic acid, monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, monofluoroacetic acid, difluoroacetic acid, trifluoroacetic acid, α-chlorobutyric acid, β-chlorobutyric acid, γ-chlorobutyric acid, lactic acid,  
20 glycolic acid, pyruvic acid, glyoxalic acid, methacrylic acid, and acrylic acid;

the sulfonic acids are at least one member selected from the group consisting of methanesulfonic acid, benzenesulfonic acid, trifluoromethanesulfonic acid, and  
25 toluenesulfonic acid; and

the polycarboxylic acids are at least one member selected from the group consisting of oxalic acid, succinic acid, adipic acid, tartaric acid, and citric acid.

26. A cleaning solution according to claim 20,  
5 further comprising water, wherein the weight ratio of HF/organic solvent/water is in the range of 0.01 to 10 mass %/49 to 99.9 mass %/0 to 50 mass %; and the organic solvent is at least one member selected from the group consisting of monohydric alcohols, polyols, ketones,  
10 amides, nitriles, aldehydes, alkylene glycol monoalkyl ethers, ethers, esters, hydrocarbons, halogen compounds, fluorinated alcohols, phosphate esters, and nitrogen-containing compounds.

27. A cleaning solution according to claim 21,  
15 wherein the weight ratio of HF/said at least one member selected from the group consisting of ammonia and amines/organic solvent/water is in the range of 0.01 to 10 mass %/0.01 to 30 mass %/49 to 99.9 mass %/0 to 50 mass %; and the organic solvent is at least one member selected  
20 from the group consisting of monohydric alcohols, polyols, ketones, amides, nitriles, aldehydes, alkylene glycol monoalkyl ethers, ethers, esters, hydrocarbons, halogen compounds, fluorinated alcohols, phosphate esters, and nitrogen-containing compounds.

25 28. A cleaning solution according to claim 26,

wherein the monohydric alcohols are at least one member selected from the group consisting of methanol, ethanol, isopropanol (IPA), 1-propanol, 1-butanol, 2-butanol, t-butanol, 2-methyl-1-propanol, 1-pentanol, 1-hexanol, 1-heptanol, 4-heptanol, 1-octanol, 1-nonyl alcohol, 1-decanol, 1-dodecanol, lauryl alcohol, and cyclohexanol;

the polyols are at least one member selected from the group consisting of ethylene glycol, diethylene glycol, 1,2-propanediol, propylene glycol, 2,3-butanediol, and glycerin;

the ketones are at least one member selected from the group consisting of acetone, acetylacetone, methyl ethyl ketone, methyl isobutyl ketone, cyclohexanone, diethyl ketone, and diisobutyl ketone;

the amides are at least one member selected from the group consisting of N-methylformamide, N,N-dimethylformamide, N-methylacetamide, and N,N-dimethylacetamide;

the nitriles are at least one member selected from the group consisting of acetonitrile, propionitrile, butyronitrile, isobutyronitrile, and benzonitrile;

the aldehydes are at least one member selected from the group consisting of formaldehyde, acetaldehyde, and propionaldehyde;

the alkylene glycol monoalkyl ethers are at

least one member selected from the group consisting of ethylene glycol monomethyl ether and ethylene glycol monoethyl ether;

the ethers are at least one member selected from  
5 the group consisting of tetrahydrofuran, dioxane, diisopropyl ether, dibutyl ether, tetrahydropyran, anisole, 1,2-dimethoxyethane, and diethylene glycol dimethyl ether;

the esters are at least one member selected from the group consisting of methyl acetate, ethyl acetate,  
10 propyl acetate, isopropyl acetate, butyl acetate, isobutyl acetate, pentyl acetate, hexyl acetate, methyl propionate, ethyl propionate, propyl propionate, isopropyl propionate, butyl propionate, isobutyl propionate, pentyl propionate, hexyl propionate, methyl butyrate, ethyl butyrate, propyl  
15 butyrate, isopropyl butyrate, butyl butyrate, isobutyl butyrate, pentyl butyrate, hexyl butyrate, methyl isobutyrate, ethyl isobutyrate, propyl isobutyrate, isopropyl isobutyrate, butyl isobutyrate, isobutyl isobutyrate, pentyl isobutyrate, hexyl isobutyrate, methyl  
20 valerate, ethyl valerate, propyl valerate, isopropyl valerate, butyl valerate, isobutyl valerate, pentyl valerate, hexyl valerate, methyl isovalerate, ethyl isovalerate, propyl isovalerate, isopropyl isovalerate, butyl isovalerate, isobutyl isovalerate, pentyl  
25 isovalerate, hexyl isovalerate, methyl caproate, ethyl

caproate, propyl caproate, isopropyl caproate, butyl  
caproate, isobutyl caproate, pentyl caproate, hexyl  
caproate, methyl caprylate, ethyl caprylate, propyl  
caprylate, isopropyl caprylate, butyl caprylate, isobutyl  
5 caprylate, pentyl caprylate, hexyl caprylate, methyl  
octanoate, ethyl octanoate, propyl octanoate, isopropyl  
octanoate, butyl octanoate, isobutyl octanoate, pentyl  
octanoate, hexyl octanoate, methyl nonanoate, ethyl  
nonanoate, propyl nonanoate, isopropyl nonanoate, butyl  
10 nonanoate, isobutyl nonanoate, pentyl nonanoate, hexyl  
nonanoate, methyl decanoate, ethyl decanoate, propyl  
decanoate, isopropyl decanoate, butyl decanoate, isobutyl  
decanoate, pentyl decanoate, hexyl decanoate, methyl  
dodecanoate, ethyl dodecanoate, propyl dodecanoate,  
15 isopropyl dodecanoate, butyl dodecanoate, isobutyl  
dodecanoate, pentyl dodecanoate, hexyl dodecanoate, methyl  
laurate, ethyl laurate, propyl laurate, isopropyl laurate,  
butyl laurate, isobutyl laurate, pentyl laurate, hexyl  
laurate, methyl acrylate, ethyl acrylate, propyl acrylate,  
20 isopropyl acrylate, butyl acrylate, isobutyl acrylate,  
pentyl acrylate, hexyl acrylate, monomethyl oxalate,  
dimethyl oxalate, monoethyl oxalate, diethyl oxalate,  
monopropyl oxalate, dipropyl oxalate, monobutyl oxalate,  
dibutyl oxalate, monomethyl succinate, dimethyl succinate,  
25 monoethyl succinate, diethyl succinate, monopropyl

- succinate, dipropyl succinate, monobutyl succinate,  
dibutyl succinate, monomethyl adipate, dimethyl adipate,  
monoethyl adipate, diethyl adipate, monopropyl adipate,  
dipropyl adipate, monobutyl adipate, dibutyl adipate,  
5 monomethyl tartrate, dimethyl tartrate, monoethyl tartrate,  
diethyl tartrate, monopropyl tartrate, dipropyl tartrate,  
monobutyl tartrate, dibutyl tartrate, monomethyl citrate,  
dimethyl citrate, monoethyl citrate, diethyl citrate,  
monopropyl citrate, dipropyl citrate, monobutyl citrate,  
10 dibutyl citrate, dimethyl phthalate, diethyl phthalate,  
dipropyl phthalate, dibutyl phthalate, dipentyl phthalate,  
dihexyl phthalate, diheptyl phthalate, dioctyl phthalate,  
dinonyl phthalate, didecyl phthalate, didodecyl phthalate,  
dimethyl terephthalate, diethyl terephthalate, dipropyl  
15 terephthalate, dibutyl terephthalate, dipentyl  
terephthalate, dihexyl terephthalate, diheptyl  
terephthalate, dioctyl terephthalate, dinonyl  
terephthalate, didecyl terephthalate, didodecyl  
terephthalate, propylene carbonate, and  $\gamma$ -butyrolactone;  
20 the hydrocarbons are at least one member  
selected from the group consisting of hexane, cyclohexane,  
octane, isooctane, benzene, and toluene;  
the halogen compounds are at least one member  
selected from the group consisting of chloroform, o-  
25 dichlorobenzene, perfluorohexane, and

perfluoromethylcyclohexane;

the fluorinated alcohols are at least one member selected from the group consisting of trifluoroethanol, pentafluoropropanol, and 2,2,3,3-tetrafluoropropanol;

5 the phosphate esters are at least one member selected from the group consisting of dimethyl phosphate, dibutyl phosphate, diphenyl phosphate, dibenzyl phosphate, trimethyl phosphate, triethyl phosphate, tripropyl phosphate, tributyl phosphate, and triphenyl phosphate;

10 and

the nitrogen-containing compounds are at least one member selected from the group consisting of tetramethylurea and N-methyl-2-pyrrolidone.

29. A method of cleaning a via hole, comprising  
15 cleaning an object that has a via hole, with at least one member selected from the group consisting of titanium compounds and polymers adhering to at least one member selected from the group consisting of the sidewall and the bottom of the via hole, by the use of the cleaning  
20 solution of claim 20.

30. A method according to claim 29, comprising treating the object while performing ultrasonic cleaning.

31. A cleaned object that can be obtained according to the method of claim 29.

25 32. A method of cleaning a capacitor,



comprising cleaning an object that has a metal capacitor upper electrode or lower electrode, with at least one member selected from the group consisting of resist residue, polymers, and titanium compounds adhering to at least one member selected from the group consisting of the sidewall, the bottom, and the surface of the electrode, by the use of the cleaning solution of claim 20.

33. A method according to claim 32, comprising treating the object while performing ultrasonic cleaning.

34. A cleaned object that can be obtained according to the method of claim 32.

35. A resist-removing solution according to claim 1, wherein the solution etches, in a treatment time of 0.1 to 120 minutes, (1) an insulating film barrier to a depth of 1 to 200 Å, (2) low-k film to a depth of 1 to 200 Å, and (3) Cu at an etching rate of no more than 10 Å/min; and the solution removes resist, antireflection coating, filling material, and etching residue including these, after dry etching in the formation of damascene and dual damascene structures for Cu/low-k multilevel interconnection.

36. A removing solution according to claim 35, wherein the insulating film barrier and the low-k film are Si-containing compounds such as SiN, SiC, SiCN, SiOC, and SiO<sub>2</sub>.

37. A removing solution according to claim 35, wherein the solution removes residue resulting from etching with a nitrogen-containing etching gas, regardless of whether plasma ashing is conducted or not.

5           38. A removing solution according to claim 35, wherein the solution removes residue after ashing with a nitrogen-containing gas.

10           39. A removing solution according to claim 35, wherein one or more inert gases are dissolved in the solution such that the oxygen partial pressure in the solution is below the oxygen partial pressure in air-saturated solution.

15           40. A removing solution according to claim 35, comprising (i) HF, (ii) a protogenic solvent, and (iii) at least one organic compound selected from the group consisting of polar protophilic solvents and polar protophobic solvents having a donor number of no more than 24, and neutral solvents; wherein the weight ratio of (i) HF (hydrogen fluoride)/(ii) protogenic solvent/(iii) said  
20           at least one organic compound selected from the group consisting of polar protophilic solvents and polar protophobic solvents having a donor number of no more than 24, and neutral solvents is in the range of (i) 0.05 to 5 mass %/(ii) 1 to 98.95 mass %/(iii) 1 to 98.95 mass %.

25           41. A removing solution according to claim 35,

comprising (i) HF, (ii) a protogenic solvent, and (iii) at least one organic compound selected from the group consisting of polar protophilic solvents and polar protophobic solvents having a donor number of no more than 24, and neutral solvents, and further comprising (iv) water; wherein the weight ratio of (i) HF (hydrogen fluoride)/(ii) protogenic solvent/(iii) said at least one organic compound selected from the group consisting of polar protophilic solvents and polar protophobic solvents having a donor number of no more than 24, and neutral solvents/(iv) water is in the range of (i) 0.05 to 5 mass %/(ii) 1 to 98.93 mass %/(iii) 1 to 98.93 mass %/(iv) 0.02 to 90 mass %.

42. A removing solution according to claim 35, comprising (i) HF, (ii) a protogenic solvent, (iii) at least one organic compound selected from the group consisting of polar protophilic solvents and polar protophobic solvents having a donor number of no more than 24, and neutral solvents, and further comprising (iv) water; wherein the weight ratio of (i) HF/(ii) protogenic solvent/(iii) said at least one organic compound selected from the group consisting of

polar protophilic solvents and polar protophobic solvents having a donor number of no more than 24, and neutral solvents/(iv) water/(v) acid/(vi) polar protophilic solvent having a donor number of at least 25/(vii) 5 fluorine-containing organic compound is in the range of (i) 0.05 to 5 mass %/(ii) 1 to 98.83 mass %/ (iii) 1 to 98.83 mass %/(iv) 0.02 to 90 mass %/(v) 0 to 10 mass %/(vi) 0 to 50 mass %/(vii) 0 to 70 mass %, with the total amount of acid, polar protophilic solvent having a 10 donor number of at least 25, and fluorine-containing organic compound being 0.1 to 74.93 mass %.

43. A removing solution according to claim 35, comprising (i) HF, (ii) a protogenic solvent, (iii) at least one organic compound selected from the group 15 consisting of polar protophilic solvents and polar protophobic solvents having a donor number of no more than 24, and neutral solvents, (iv) water, and at least one member selected from the group consisting of (v) acids, solvent/(iii) said at least one organic compound selected from the group consisting of polar protophilic solvents 25 and polar protophobic solvents having a donor number of no

more than 24, and neutral solvents/(iv) water/(v)  
acid/(vi) polar protophilic solvent having a donor number  
of at least 25/(vii) fluorine-containing organic  
compound/(viii) ammonia and/or amine is in the range of  
5 (i) 0.05 to 5 mass %/(ii) 1 to 98.73 mass %/(iii) 1 to  
98.73 mass %/(iv) 0.02 to 90 mass %/(v) 0 to 10  
mass %/(vi) 0 to 50 mass %/(vii) 0 to 70 mass %/(viii)  
0.05 to 10 mass %, with the total amount of acid, polar  
protophilic solvent having a donor number of at least 25,  
10 and fluorine-containing organic compound being 0.1 to  
74.83 mass %.

44. A removing solution according to claim 35,  
comprising (i) HF, (ii) at least one organic compound  
selected from the group consisting of polar protophilic  
15 solvents and polar protophobic solvents having a donor  
number of no more than 24, neutral solvents, and  
protogenic solvents, and (iii) water; wherein the weight  
ratio of (i) HF (hydrogen fluoride)/(ii) said at least one  
0.05 to 5 mass %/(ii) 85 to 99.93 mass %/(iii) 0.02 to 10  
mass %.

25 45. A removing solution according to claim 35,

comprising (i) HF, (ii) at least one organic compound selected from the group consisting of polar protophilic solvents and polar protophobic solvents having a donor number of no more than 24, neutral solvents, and  
5 protogenic solvents, and (iii) water, and further comprising at least one member selected from the group consisting of acids, polar protophilic solvents having a donor number of at least 25, and fluorine-containing organic compounds; wherein the weight ratio of (i) HF/(ii)  
10 said at least one organic compound selected from the group consisting of polar protophilic solvents and polar protophobic solvents having a donor number of no more than 24, neutral solvents, and protogenic solvents/(iii) water/(iv) acid/(v) polar protophilic solvent having a  
15 donor number of at least 25/(vi) fluorine-containing organic compound is in the range of (i) 0.05 to 5 mass %/(ii) 25 to 99.83 mass %/(iii) 0.02 to 10 mass %/(iv) 0 to 10 mass %/(v) 0 to 50 mass %/(vi) 0 to 70 mass %, with the total amount of acid, polar protophilic  
20 solvent having a donor number of at least 25, and fluorine-containing organic compound being 0.1 to 74.93 mass %.

46. A removing solution according to claim 35,  
comprising (i) HF, (ii) at least one organic compound  
25 selected from the group consisting of polar protophilic

solvents and polar protophobic solvents having a donor number of no more than 24, neutral solvents, and protogenic solvents, (iii) water, and at least one member selected from the group consisting of (iv) acids, (v) 5 polar protophilic solvents having a donor number of at least 25, and (vi) fluorine-containing organic compounds, and further comprising (vii) ammonia and/or amine(s); wherein the weight ratio of (i) HF/(ii) said at least one organic compound selected from the group consisting of 10 polar protophilic solvents and polar protophobic solvents having a donor number of no more than 24, neutral solvents, and protogenic solvents/(iii) water/(iv) acid/(v) polar protophilic solvent having a donor number of at least 25/(vi) fluorine-containing organic compound/(viii) 15 ammonia and/or amine is in the range of (i) 0.05 to 5 mass %/(ii) 25 to 99.78 mass %/(iii) 0.02 to 10 mass %/(iv) 0 to 10 mass %/(v) 0 to 10 mass %/(vi) 0 to 70 mass %/(vii) 0.05 to 10 mass %, with the total amount of said at least one member selected from the group 20 consisting of acids, polar protophilic solvents having a donor number of at least 25, and fluorine-containing organic compounds being 0.1 to 74.88 mass %.

47. A removing solution according to claim 40, wherein the neutral solvents are alcohols; the protogenic 25 solvents are monocarboxylic acids, polycarboxylic acids,

and sulfonic acids; and the polar aprotic solvents having a donor number of no more than 24 are esters and ethers; and the polar protophilic solvents having a donor number of at least 25 are esters, ethers, ketones, and acid  
5 anhydrides.

48. A removing solution according to claim 47, wherein (I) as the neutral solvents, the alcohols are methyl alcohol, ethyl alcohol, propanol, isopropanol, t-butanol, allyl alcohol, and ethylene glycol;

10 (II) as the protogenic solvents, the monocarboxylic acids are formic acid, acetic acid, propionic acid, butyric acid, isobutyric acid, monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, monofluoroacetic acid,  
15 difluoroacetic acid, trifluoroacetic acid,  $\alpha$ -chlorobutyric acid,  $\beta$ -chlorobutyric acid,  $\gamma$ -chlorobutyric acid, lactic acid, glycolic acid, pyruvic acid, glyoxalic acid, methacrylic acid, and acrylic acid; the polycarboxylic acids are oxalic acid, succinic acid, adipic acid, and  
20 citric acid; and the sulfonic acids are methanesulfonic acid, benzenesulfonic acid, toluenesulfonic acid, and trifluoromethanesulfonic acid;

(III) as the polar protophilic solvents having a donor number of no more than 24, the esters are tributyl  
25 phosphate and trimethyl phosphate; the ethers are 1,2-



dimethoxyethane, tetrahydrofuran, diethyl ether, ethylene glycol monomethyl ether, ethylene glycol monoethyl ether, dimethoxymethane, dimethoxypropane, diethoxymethane, and 1,1-dimethoxyethane;

5 (IV) as the polar protophobic solvents, the esters are methyl acetate, ethyl acetate, butyl acetate, propylene carbonate, ethylene carbonate, ethylene sulfite, and lactone; the ethers are dioxane, trioxane, and diglyme; the ketones are acetone; and the acid anhydrides  
10 are acetic anhydride.

49. A removing solution according to claim 42, 43, 45, or 46, wherein the acids are at least one member selected from the group consisting of hydrogen chloride, hydrogen bromide, hydrogen iodide, aqueous solutions  
15 thereof, sulfuric acid, nitric acid, phosphoric acid, and carboxylic acid.

50. A removing solution according to claim 42, 43, 45, or 46, wherein the fluorine-containing organic compounds are fluorine-containing ethers such as  
20  $\text{CHF}_2\text{CF}_2\text{OCH}_2\text{CF}_3$  and  $\text{CHF}_2\text{CF}_2\text{OCH}_3$ ; and hydrochlorofluorocarbons (HCFCs) such as  $\text{CH}_3\text{CCl}_2\text{F}$  and  $\text{CCl}_2\text{F}_2\text{CH}_2\text{ClF}$ .

51. A removing solution according to claim 42, 43, 45, or 46, wherein the polar protophilic solvents  
25 having a donor number of at least 25 are at least one

member selected from the group consisting of amides such as dimethylformamide, dimethylacetamide, hexamethylphosphoric triamide, N-methyl-2-pyrrolidone, 1,1,3,3-tetramethylurea, N-methylpropionamide, and  
5 dimethyl imidazolidinone; and sulfur compounds such as dimethyl sulfoxide, sulfolane, dimethylthioformamide, and N-methylthiopyrrolidone.

52. A removing solution according to any of claims 40 to 46, wherein the solution comprises a  
10 carboxylic acid as a protogenic solvent; and at least one member selected from the group consisting of alcohols as neutral solvents, and esters and ethers as polar aprotic solvents having a donor number of no more than 24.

53. A removing solution according to claim 52,  
15 wherein the carboxylic acid is acetic acid.

54. A removing solution according to claim 47, wherein the solution comprises an alcohol as a neutral solvent; and at least one member selected from the group  
the group consisting of propanol, isopropanol, t-butanol, allyl alcohol, and ethylene glycol.

25 56. A removing solution according to any of

claims 40 to 46, wherein the solution comprises at least one member selected from the group consisting of esters and ethers as polar aprotic solvents having a donor number of no more than 24.

- 5                    57. A removing solution according to any of  
claims 40 to 46, wherein the esters are at least one  
member selected from the group consisting of methyl  
acetate, ethyl acetate, butyl acetate, propylene carbonate,  
and ethylene carbonate; and the ethers are at least one  
10 member selected from the group consisting of 1,2-  
dimethoxyethane, tetrahydrofuran, dioxane, trioxane,  
diglyme, ethylene glycol monomethyl ether, ethylene glycol  
diethyl ether, diethylene glycol methyl ethyl ether,  
tetraethylene glycol dimethyl ether, polyethylene glycol  
15 dimethyl ether, ethylene glycol monoallyl ether,  
diethylene glycol monobutyl ether, ethylene glycol butyl  
ether, triethylene glycol monobutyl ether, diethylene  
glycol diethyl ether, diethylene glycol dimethyl ether,  
propylene glycol monomethyl ether, tripropylene glycol  
monomethyl ether, ethylene glycol monoethyl ether,  
25 polyethylene glycol monomethyl ether, triethylene glycol

monomethyl ether, propylene glycol monopropyl ether, and ethylene glycol methyl ethyl ether.

58. A removing solution according to claim 44, comprising HF, acetic acid, and water; wherein the weight  
5 ratio of HF/acetic acid/water is in the range of 0.05 to 5 mass %/85 to 99.93 mass %/0.02 to 10 mass %.

59. A removing solution according to claim 44, comprising HF, isopropanol, and water; wherein the weight  
ratio of HF/isopropanol/water is in the range of 1 to 7  
10 mass %/88 to 98.5 mass %/0.5 to 5 mass %.

60. A removing solution according to claim 44, comprising HF, acetic acid, isopropanol, and water; wherein the weight ratio of HF/acetic acid/isopropanol/  
water is in the range of 0.05 to 6 mass %/1 to 98.93  
15 mass %/1 to 98.85 mass %/0.02 to 12 mass %.

61. A removing solution according to claim 44, comprising HF, 1,2-dimethoxyethane, and water; wherein the weight ratio of HF/1,2-dimethoxyethane/water is in the  
range of 0.50 to 5 mass %/85.00 to 99.3 mass %/0.02 to 10  
20 mass %.

62. A removing solution according to claim 44, comprising HF; at least one member selected from the group consisting of methyl acetate, ethyl acetate, and butyl  
acetate; and water; wherein the weight ratio of HF/said at  
25 least one member selected from the group consisting of

methyl acetate, ethyl acetate, and butyl acetate/water is in the range of 0.50 to 5 mass %/85.00 to 99.30 mass %/0.02 to 10 mass %.

63. A removing solution according to claim 44,  
5 comprising HF, 1,4-dioxane, and water; wherein the weight ratio of HF/1,4-dioxane/water is in the range of 0.50 to 5 mass %/85.00 to 99.3 mass %/0.2 to 10 mass %.

64. A removing solution according to claim 44,  
comprising HF; 1,4-dioxane and at least one member  
10 selected from the group consisting of acetic anhydride and acetic acid; and water; wherein the weight ratio of HF/  
1,4-dioxane and said at least one member selected from the group consisting of acetic anhydride and acetic acid/water  
is in the range of 0.50 to 6 mass %/82.00 to 99.30 mass %/  
15 0.2 to 12 mass %.

65. A removing solution according to claim 44,  
comprising HF; at least one member selected from the group consisting of ethylene glycol monomethyl ether, ethylene glycol diethyl ether, diethylene glycol methyl ethyl ether,  
20 tetraethylene glycol dimethyl ether, polyethylene glycol dimethyl ether, ethylene glycol monoallyl ether,  
diethylene glycol monobutyl ether, ethylene glycol butyl ether, triethylene glycol monobutyl ether, diethylene glycol diethyl ether, diethylene glycol dimethyl ether,  
25 triethylene glycol dimethyl ether, diethylene glycol

monoisobutyl ether, ethylene glycol monoisobutyl ether,  
ethylene glycol monoisopropyl ether, diethylene glycol  
monomethyl ether, dipropylene glycol monomethyl ether,  
propylene glycol monomethyl ether, tripropylene glycol  
5 monomethyl ether, ethylene glycol monoethyl ether,  
polyethylene glycol monomethyl ether, triethylene glycol  
monomethyl ether, propylene glycol monopropyl ether, and  
ethylene glycol methyl ethyl ether; and water; wherein the  
weight ratio of HF/said at least one member selected from  
10 the group consisting of ethylene glycol monomethyl ether,  
ethylene glycol diethyl ether, diethylene glycol methyl  
ethyl ether, tetraethylene glycol dimethyl ether,  
polyethylene glycol dimethyl ether, ethylene glycol  
monoallyl ether, diethylene glycol monobutyl ether,  
15 ethylene glycol butyl ether, triethylene glycol monobutyl  
ether, diethylene glycol diethyl ether, diethylene glycol  
dimethyl ether, triethylene glycol dimethyl ether,  
diethylene glycol monoisobutyl ether, ethylene glycol  
monoisobutyl ether, ethylene glycol monoisopropyl ether,  
20 diethylene glycol monomethyl ether, dipropylene glycol  
monomethyl ether, propylene glycol monomethyl ether,  
tripropylene glycol monomethyl ether, ethylene glycol  
monoethyl ether, polyethylene glycol monomethyl ether,  
triethylene glycol monomethyl ether, propylene glycol  
25 monopropyl ether, and ethylene glycol methyl ethyl ether/

water is in the range of 0.50 to 5 mass %/85.00 to 99.30 mass %/0.20 to 10 mass %.

66. A removing solution according to claim 35, comprising HF, methanesulfonic acid, and water; wherein  
5 the weight ratio of HF/methanesulfonic acid/water is in the range of more than 0 and not more than 5 mass %/at least 45 and less than 100 mass %/more than 0 and not more than 50 mass %.

67. A removing method comprising removing  
10 etching residue while leaving low-k film that has been damaged by a plasma process, by the use of the removing solution of claim 1 or 35.

68. A method according to claim 15 or 67, comprising performing a removal treatment under an  
15 atmosphere (substantially in inert gas) wherein one or more inert gases are mixed such that the atmosphere has an oxygen partial pressure below the oxygen partial pressure in air.

69. A rinse treatment method for removing a  
20 removing solution from an object treated by the method of claim 15 or 67, comprising performing a rinse treatment using water wherein one or more inert gases are dissolved such that the oxygen partial pressure in the water is below the oxygen partial pressure in air-saturated  
25 solution, under an atmosphere (substantially in inert gas)

wherein one or more inert gases are mixed such that the atmosphere has an oxygen partial pressure below the oxygen partial pressure in air.

70. A removal-treated object that can be  
5 obtained by treatment according to the removing method of claim 67 or 68, and the rinse treatment method of claim 69.

71. A cleaning solution for a via hole or a capacitor according to claim 20, wherein the removing solution of claim 35 is used to clean the via hole or the  
10 capacitor.

72. A method of cleaning a via hole according to claim 29 or a method of cleaning a capacitor according to claim 32, comprising using the cleaning solution for a via hole or a capacitor of claim 71.

73. A cleaned object that can be obtained by  
15 cleaning treatment using the cleaning solution for a via hole or a capacitor of claim 71.